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A COST-EFFECTIVENESS STUDY OF AIR POLLUTION ABATEMENT IN THE GREATER KANSAS CITY AREA

Ernst and Ernst

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AIR POLLUTION ABATEMENT

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GREATER KANSAS CITY AREA

Summary Statement by Ernst & Ernst to the
Kansas City, Kansas - Kansas City, Missouri
Air Pollution Abatement Conference

May, 1968

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I. INTRODUCTION

Mr. Presiding Officer, conference members, ladies and gentlemen. My name is Thomas M. Keyes. I am a partner in the Kansas City, Missouri office of Ernst & Ernst, a certified public accounting and management consulting firm.

We will present today the principal results of a contract study for the U. S. Public Health Service to develop, under certain assumptions, estimates of the cost and effectiveness of several possible abatement strategies for achieving various air quality levels in the Kansas City, Kansas-Kansas City, Missouri study area.

The study applied a form of systems analysis in which a number of interrelated computer programs, data files, and analytical techniques together simulate the overall impact of emission controls on the long-term pollution levels of suspended particulates and sulfur oxides. Since the computed costs and efficiencies of these controls are based on data originally compiled by others and not subject to our independent verification, our results should be viewed as approximations rather than as precise figures. However, for comparative purposes these results have more precision and can therefore aid in the formulation of alternative strategies for air pollution abatement in the Kansas City area since they reflect local conditions as expressed by available data on emissions, meteorology, and other relevant factors. A written report, which sets forth the study limitations and assumptions in considerable detail, will shortly be available to enlarge upon the principal results discussed today. The report will be submitted as an exhibit as soon as it becomes available.

Now I would like to introduce Mr. Ellison S. Burton of the Washington, D. C. office of Ernst & Ernst who has been the project director of the study and who will present the study results.

II. SUMMARY OF STUDY RESULTS

Thank you, Mr. Keyes. Mr. Presiding Officer, conference members, ladies and gentlemen. My name is Ellison S. Burton. I am a member of the Management Services Division of Ernst & Ernst and the project director of our study for the Public Health Service.

Mr. Keyes mentioned that our objective was to estimate the cost of achieving various air quality levels in the Kansas City study area under different abatement strategies. The numerical data providing the basis for the study have come from agencies of the federal, state, and local governments, manufacturers of emission control equipment, public utilities, process industries, trade associations, fuel suppliers, consultants, and others. These sources are referenced in our exhibit to be submitted. The Public Health Service, in particular, provided for study purposes detailed data on emission sources and all meteorological inputs.

I'll proceed by describing, first, the pollutants considered in the study; second, the types of emission sources of these pollutants surveyed; third, the emission control alternatives postulated; and last, the estimated cost of abatement approaches based on these alternatives.

The pollutants of interest in this study are suspended particulates and the sulfur oxides whose emissions were quantitated in the Public Health Service emission survey of the Kansas City study area. Other pollutants are not considered.

First slide, please. (Figure I)

We are looking at a picture of the estimated pollution levels of suspended particulates superimposed on a map of the area. The heavy contours are called iso-intensity lines and connect points of equal annual average concentrations in micrograms per cubic meter ($\mu Gms/M^3$). These iso-intensity lines and others I will show are based on the emission survey mentioned which shows over 59,000 tons of particulates emitted annually in the study area. A meteorological model developed by the Public Health Service uses average wind patterns to translate the surveyed emissions into concentrations on the ground at selected receptor points. By adding up the concentrations contributed by all sources to each of the receptor points, the iso-intensity lines can be interpolated. The estimated annual average concentrations of suspended particulates range from less than 50 $\mu Gms/M^3$ to over 150 $\mu Gms/M^3$. Notice that several high concentration points are estimated by the model. These concentrations correspond well to actual observations near those points. The highest predicted particulate concentration supported by actual observations is about 184 $\mu Gms/M^3$.

Next slide, please. (Figure II)

These are the estimated annual average iso-intensity lines for sulfur oxides based on the meteorological model. The concentrations here range from less than 0.015 parts per million (ppm) to over 0.045 ppm. A peak annual average of 0.046 ppm was estimated by the model which corresponds well to observed data. The annual emissions of sulfur oxides in the area amount to over 124,000 tons.

Next slide, please. (Table I)

This is a list of the types of emission sources of suspended particulates and sulfur oxides found in the Kansas City study area. These aggregated sources account for the percentages shown of the total annual tonnages of the two pollutants in this area. These emissions come from combustion of fossil fuels for space heating and power generation, from open burning and incineration of solid and liquid waste, from industrial processes, and from miscellaneous small sources. Stationary sources account for over 86 percent of the particulates and over 96 percent of the sulfur oxides emitted in this area according to the recent Public Health Service emission survey.

Next slide, please. (Figure III)

This figure shows the emission control alternatives provided in this study for the stationary sources. Control of mobile source emissions was not studied.

This diagram shows the fuel and hardware alternatives for emission control which are available to major combustion sources presently using either coal or residual oil and to major industrial process sources. A major source emits over 100 tons of a pollutant per year. One hundred twenty-nine major sources were included in the emission inventory of the Kansas City study area. Suppose a source is now burning a high sulfur coal. Then there are several paths which can be taken to achieve reduced emission levels. Substitution of a lower sulfur coal would result in reduced sulfur oxide emissions, but in little or no reduction in particulates. To reduce the particulates, a mechanical device, a multiple cyclone, could be installed. Another device, an electrostatic precipitator, could be added in series with the collector to increase particulate reduction to as much as 99.5 percent of the uncontrolled emissions

of a coal-fired source. Other alternatives were also postulated. For example, a possibility for one power plant in the area is to retain the present high sulfur, high ash coal but to install a stack gas cleaning system. Another possibility is for a coal or residual oil user to switch to natural gas. Some alternatives were not considered, such as relocation of a source, switching to atomic energy, or building a high smoke stack. For the thousands of small fuel sources in the model, the only alternative stipulated was for coal users to substitute a coal with as low as 1 percent sulfur by weight. No mechanical controls were allowed for small sources because of prohibitive costs. It was assumed that the sulfur content of the coal presently used ran as high as 4 percent, and the sulfur content of the residual oil presently used as high as 2.5 percent.

In reality, no two emission sources are identical, and seemingly small differences in physical plant can imply, for some control alternatives, significantly different problems of technical and economic feasibility. For this reason, control alternatives were selected to be compatible with the principal characteristics of each of the major sources listed in the Public Health Service emission survey. Present levels of emission control were considered. Ranges of cost were estimated for each alternative, broken down into cost per BTU for fuels, purchase, installation, and maintenance and operating costs for mechanical equipment, boiler conversion costs for switching types of fuels, and the cost of terminating the burning of waste and substituting sanitary landfill operations. A 15-year depreciation of capital equipment has been assumed. An amount equal to the depreciation has been included to cover interest, insurance, taxes, and other miscellaneous charges.

Since fuels of different sulfur levels can be used in combination with an array of mechanical equipment, each component of which can have a different designed efficiency, there can be as many as 50 different possibilities which exist for each source to control the particulate and sulfur oxides emissions. For 129 major sources, therefore, an astronomical number of combinations exist for simulating the reduction of the two pollutants over the Kansas City study area. Some selectivity is obviously necessary in choosing abatement strategies, for while the computer may be able to calculate the cost and effectiveness of all combinations, only relatively few are of interest from the point of view of area-wide abatement.

When we choose a strategy we have in mind an objective to be achieved and the cost to achieve it. In this study, our objectives were to compute the estimated annual dollar cost of achieving certain reductions either at the point of maximum concentration of the pollutants or in the total tonnage of pollutants emitted. Control agency administrative costs to implement a strategy are not included in these estimates.

First, what is the greatest possible reduction of the two pollutants and what is the estimated annual cost of this reduction?

Next slide, please. (Figure IV)

You will recall that the present maximum annual average concentration of suspended particulates was estimated to be 184 $\mu Gms/M^3$. The greatest reduction strategy reduces the maximum concentration to 85 $\mu Gms/M^3$. This figure shows the resulting iso-intensity lines. To achieve this, the total annual emissions of particulates are reduced 69 percent from 59,000 tons to less than 19,000 tons. This strategy simultaneously reduces the peak sulfur oxides

concentration 69 percent from 0.046 ppm to 0.015 ppm. The associated total annual emissions of sulfur oxides are reduced 81 percent from 124,000 tons to less than 24,000 tons. The estimated cost of this maximum abatement strategy is $26,400,000 annually. As it happens, this is also the highest cost for any abatement strategy we have allowed.

Next slide, please. (Figure V)

For comparison purposes, we have plotted in this figure all of the principal strategies simulated in this study and a summary of their effectiveness.

The vertical axis is estimated annual cost in millions of dollars; the horizontal axis is the predicted maximum annual average concentration of suspended particulates at any point in the Kansas City study area. The top-most point in this figure locates the maximum control strategy already discussed. The bottom-most point locates the lowest cost strategy. The lowest cost strategy results in an estimated total cost reduction of over $700,000 from the base conditions but without changing the pollution values significantly. While this may be surprising, it is explained by the fact that based on present fuel costs some sources can apparently effect operating cost reductions by buying fuels which are cheaper than those now being used.

I hasten to point out that the individual controls comprising any simulated strategy represent only possibilities, not certainties. A number of factors may dictate against the actual implementation of any particular control action in practice. For example, because of cost versus savings trade-offs a fuel user may not elect to interrupt his operations while converting a boiler to take advantage of a cheaper fuel alternative.

The curve connecting the cost of the maximum control strategy to the lowest cost contains all of the least cost solutions for reducing the maximum concentration of suspended particulates without deliberately controlling sulfur oxides. The curve which merges with it connects all the least cost strategies for reducing the maximum concentration of suspended particulates while requiring that the initial maximum concentration of sulfur oxides, 0.046 ppm, be reduced by half to 0.023 ppm. We show these least cost curves as smooth curves for convenience; they are actually made up of a large number of discrete steps, since there are only a finite number of possible strategies. A least cost solution is defined as that combination of emission controls which achieves a stated objective for the least total annual cost to the whole community. For example, with no deliberate sulfur oxides control a simulated reduction of the initial maximum concentration of suspended particulates from 184 $\mu Gms/M^3$ to 120 $\mu Gms/M^3$ can be achieved with a 22 percent reduction in particulate emission for no net increase in the estimated annual cost. Reduction to 89 $\mu Gms/M^3$ can be achieved for an estimated cost of $5,000,000 annually with a 59 percent reduction in emissions. Reduction to 86 $\mu Gms/M^3$ can be achieved, with a 68 percent reduction in emissions for an estimated $7,000,000 annually with a bonus reduction of the maximum concentration of sulfur oxides to 0.040 ppm. For another $500,000 annually the maximum sulfur oxides concentration can be reduced to 0.023 ppm with a 42 percent reduction in emissions. Comparing these least cost solutions to the maximum control strategy provides a rather dramatic example of the law of diminishing returns in terms of reductions both in maximum concentrations and in total emissions.

It is true, of course, that a least cost solution selects those emission sources which can get the most abatement per dollar, so that some sources may not be affected. Is there, then, a more equitable, if perhaps more costly, strategy? Suppose that every source is required to reduce its particulate emissions in concert with all other sources successively by at least 20, 40, 60, 80, and maximum percent of its base emissions. The results of at least a 20 percent reduction show that the maximum concentration of suspended particulates is reduced to 89 $\mu Gms/M^3$ with a 59 percent reduction in total annual particulate emissions for an estimated cost of over $16,000,000 annually. The corresponding least cost solution has an estimated annual cost only one third of that. The next slide compares the simulated emission reductions obtained by the major types of sources under the two strategies.

Next slide, please. (Table II)

This table shows what percentage of emission reduction is obtained by each of the major emission source types for each strategy and the associated costs. It is apparent that while the least cost strategy is more highly selective, the so-called equi-proportional strategy has the more disproportionate impact on the emission sources in terms of both emission reduction and cost. The reason for this is that it costs no more for many sources to control their particulate emissions to the maximum than it does to control precisely 20 percent. Except for process changes or improved process operation, which were not considered, most mechanical equipment for particulate control has collection efficiencies in excess of 80 percent. Thus, the first step in control for many sources takes them to maximum control. This is demonstrated further by our previous figure.

Last slide, please. (Figure V)

Note that for an additional $9,000,000 annually the maximum particulate control strategy effects only a 16 percent increase in particulate emission reduction over the first equi-proportional step. This implies that in the computer simulation many sources went to maximum control in that first step. The simulated equi-proportional emission reductions of 40, 60, or 80 percent do not generate further significant reductions either in concentrations or in total emissions; the only significant change is increased cost.

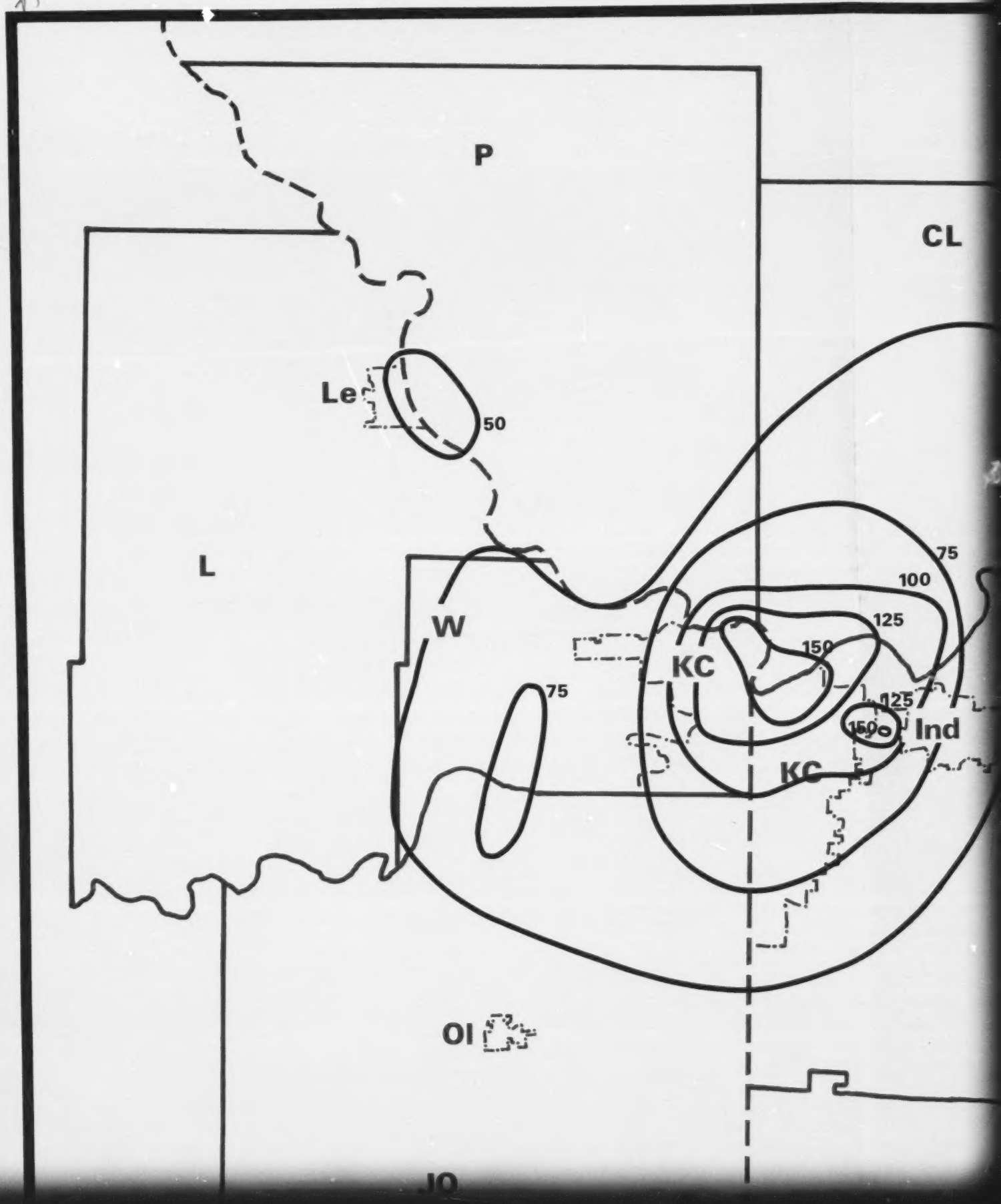
A strategy of interest for controlling the emissions of sulfur oxides is to restrict the sulfur content of fuels to 2 percent by weight or less. The estimated cost is $3,500,000 annually in increased fuel costs. This strategy reduces the sulfur oxides peak concentration to 0.035 ppm and effects a 38 percent reduction in the total tonnage of sulfur oxides emitted, while providing a bonus reduction of 10 percent in particulate emissions as well. In contrast, we note a least cost solution which halves the peak concentration and reduces the sulfur oxides emissions by 40 percent with no overall increase in annual cost.

In conclusion, I would like to note that the cost estimates presented here, and in the exhibit to be submitted, do not take into account future price fluctuations, deterioration of equipment, availability of low sulfur fuels, and several other factors which would have to be reckoned with in a precise determination of costs. But subject to these factors and to the reliability of the data used, they provide estimates of the magnitude of costs involved and provide comparative data for achieving different levels of air quality and waste load reduction. In our forthcoming exhibit ranges of cost will be included for most estimates based on the sources of information reported. The figures presented here lie within those ranges.

It should be emphasized that the results represent answers to the questions asked of the abatement simulation program developed for the Kansas City study area. The results would have to be modified of course for conditions other than those assumed and for different geographic definitions, but the simulation approach has great flexibility as a systems analysis tool and can be applied to other geographies and other pollution conditions to gain a better understanding of cost-effectiveness relationships.

We hope that the results presented today can aid this conference in developing recommendations for achieving clean air in the Kansas City area.

Thank you.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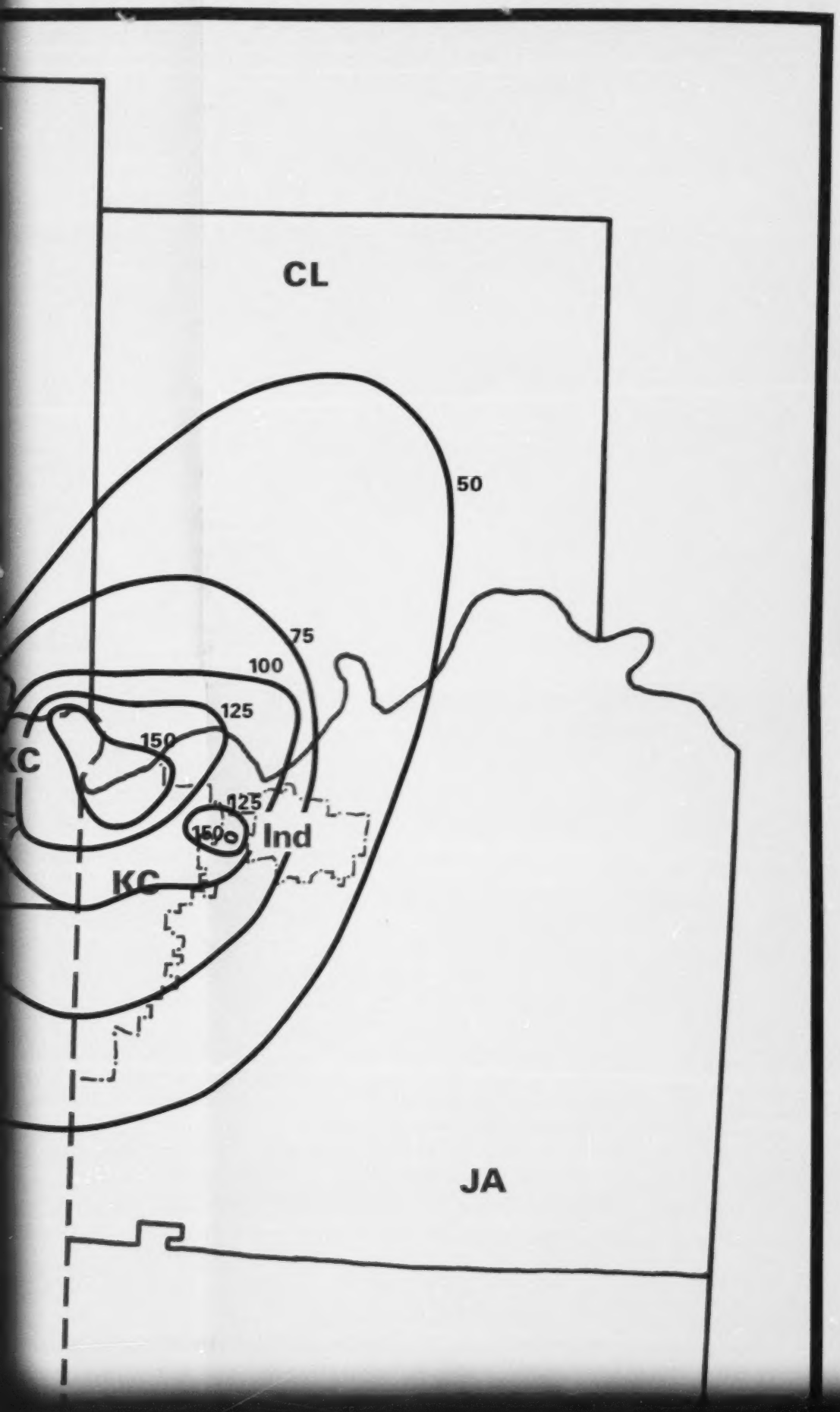

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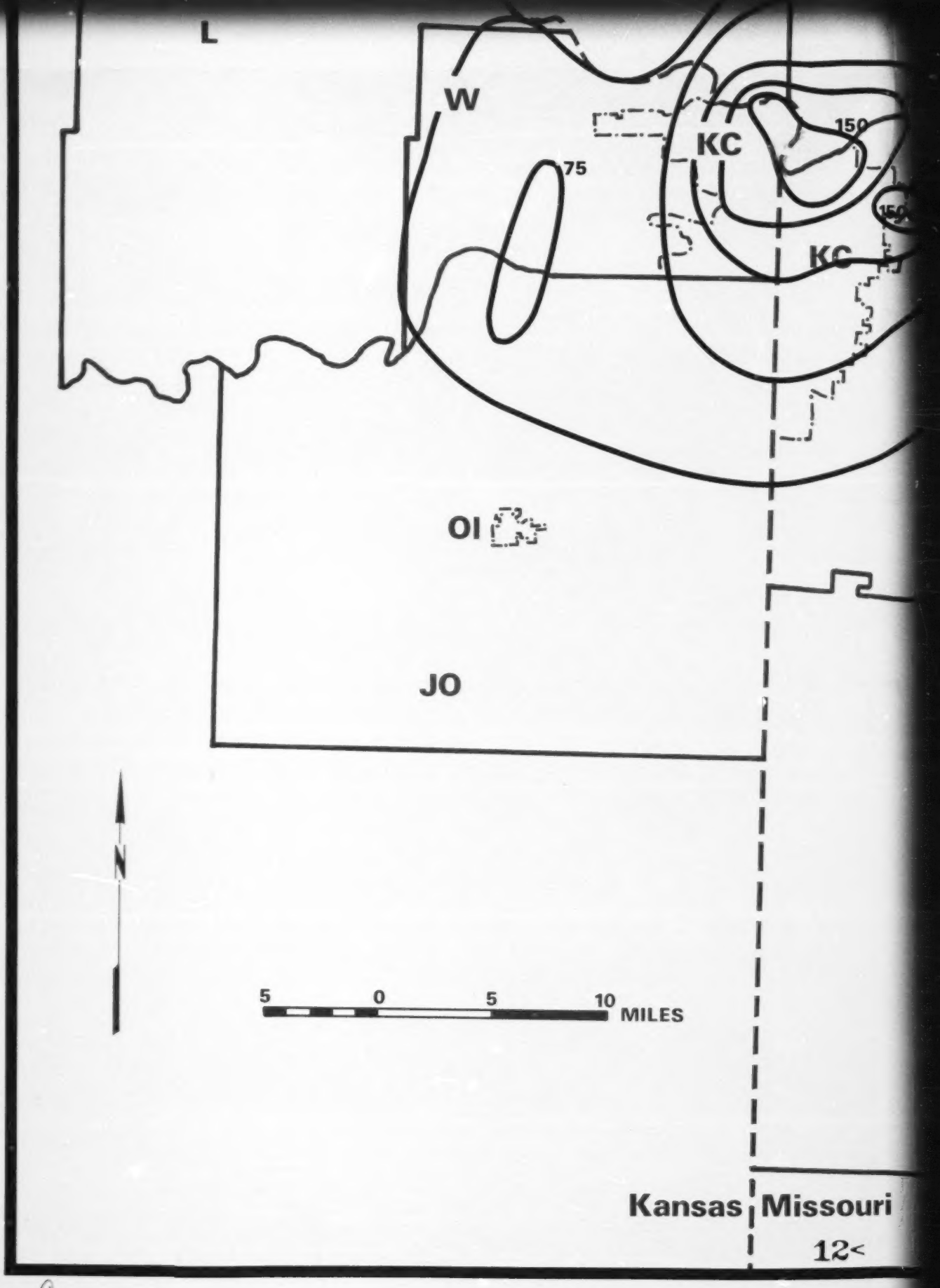
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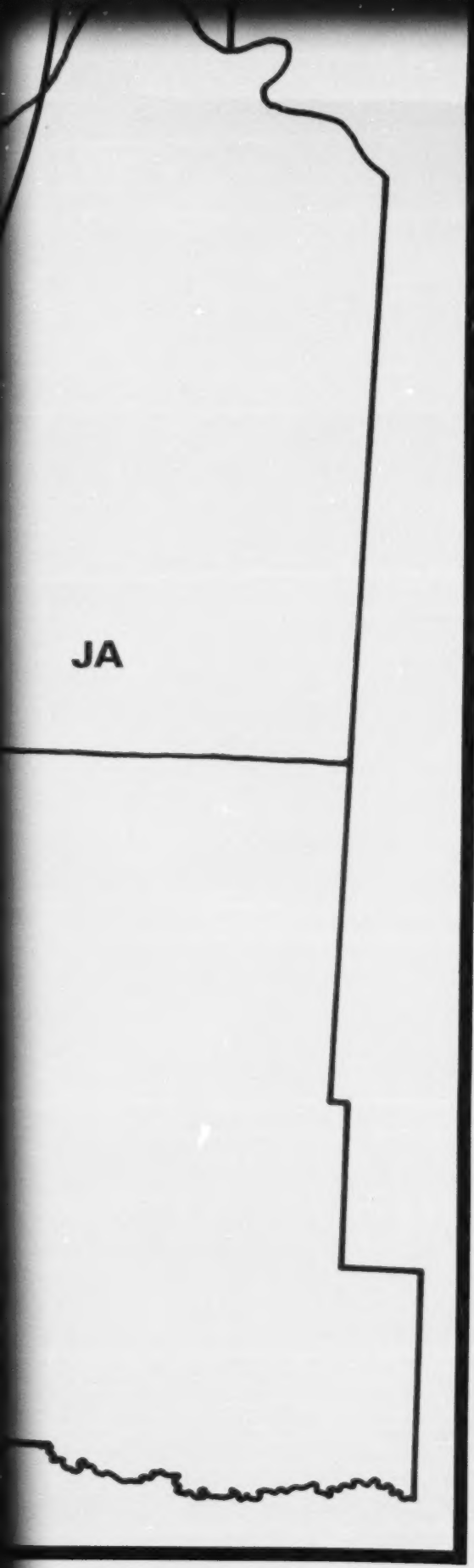


LEGEND

Iso-intensity Line

$\mu Gm/M^3$ Micrograms Per Cubic Meter (Annual Average)

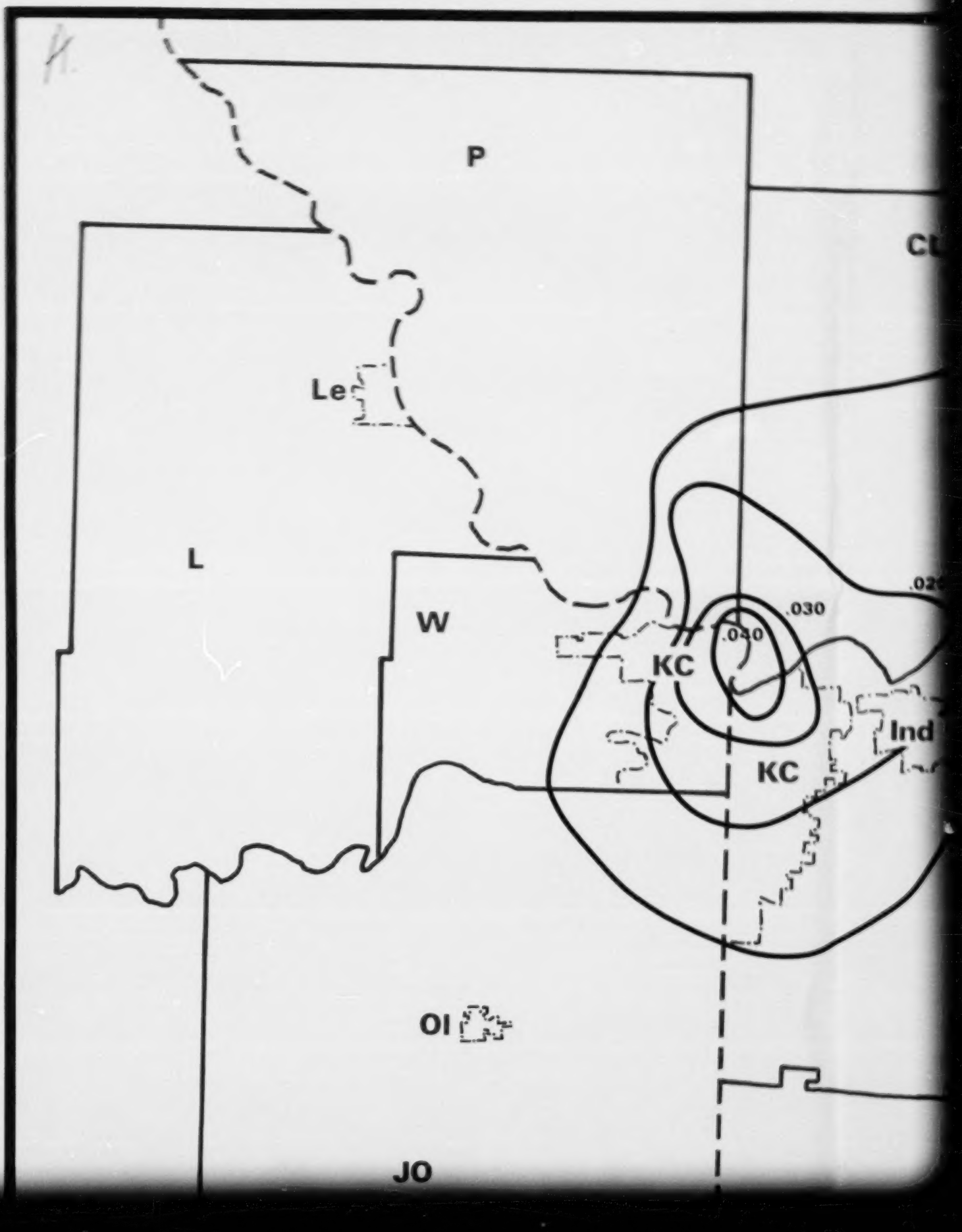
KANSAS CITY STUDY AREA

CA	Cass County
CL	Clay County
Ind	Independence
JA	Jackson County
JO	Johnson County
KC	Kansas City
L	Leavenworth County
Le	Leavenworth
Ol	Olathe
P	Platte County
W	Wyandotte County

FIGURE 1

PRE-ABATEMENT CONCENTRATIONS OF SUSPENDED PARTICULATES ($\mu Gm/M^3$)

ERNST & ERNST
Washington, D. C.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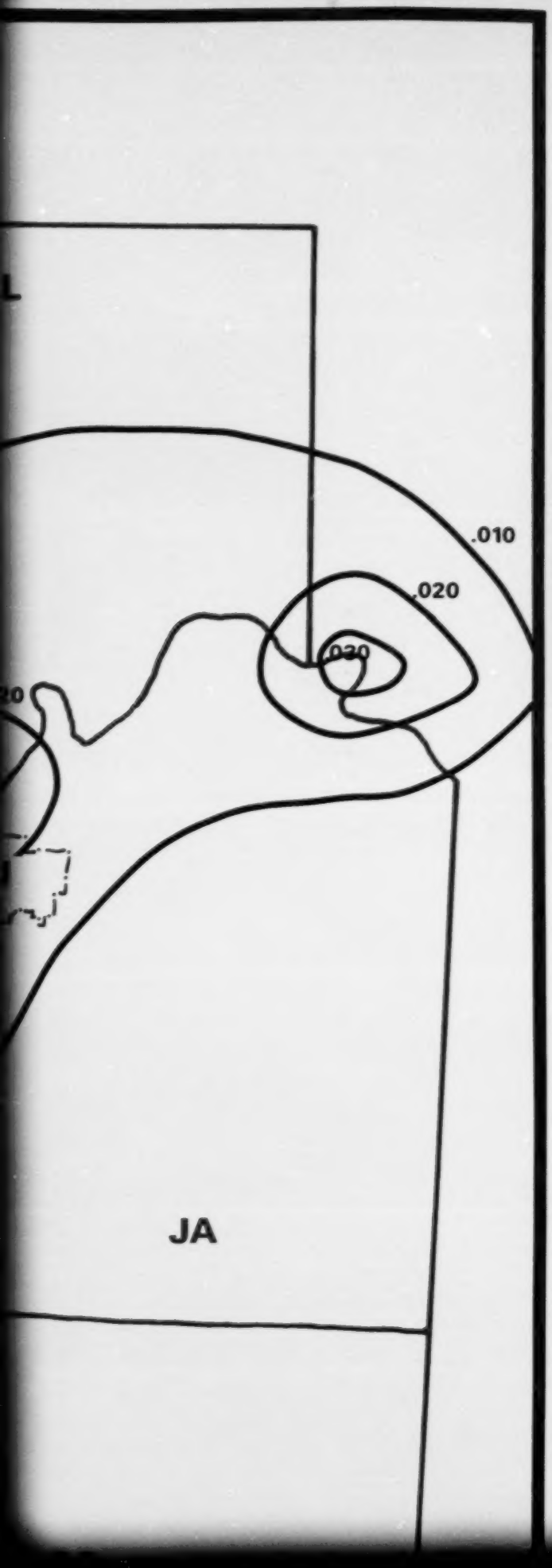

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LEGEND

———	Iso-intensity Line
PPM	Parts Per Million (Annual Average)

KANSAS CITY STUDY AREA

CA	Cass County
CL	Clay County
Ind	Independence
JA	Jackson County
JO	Johnson County
KC	Kansas City
L	Leavenworth County
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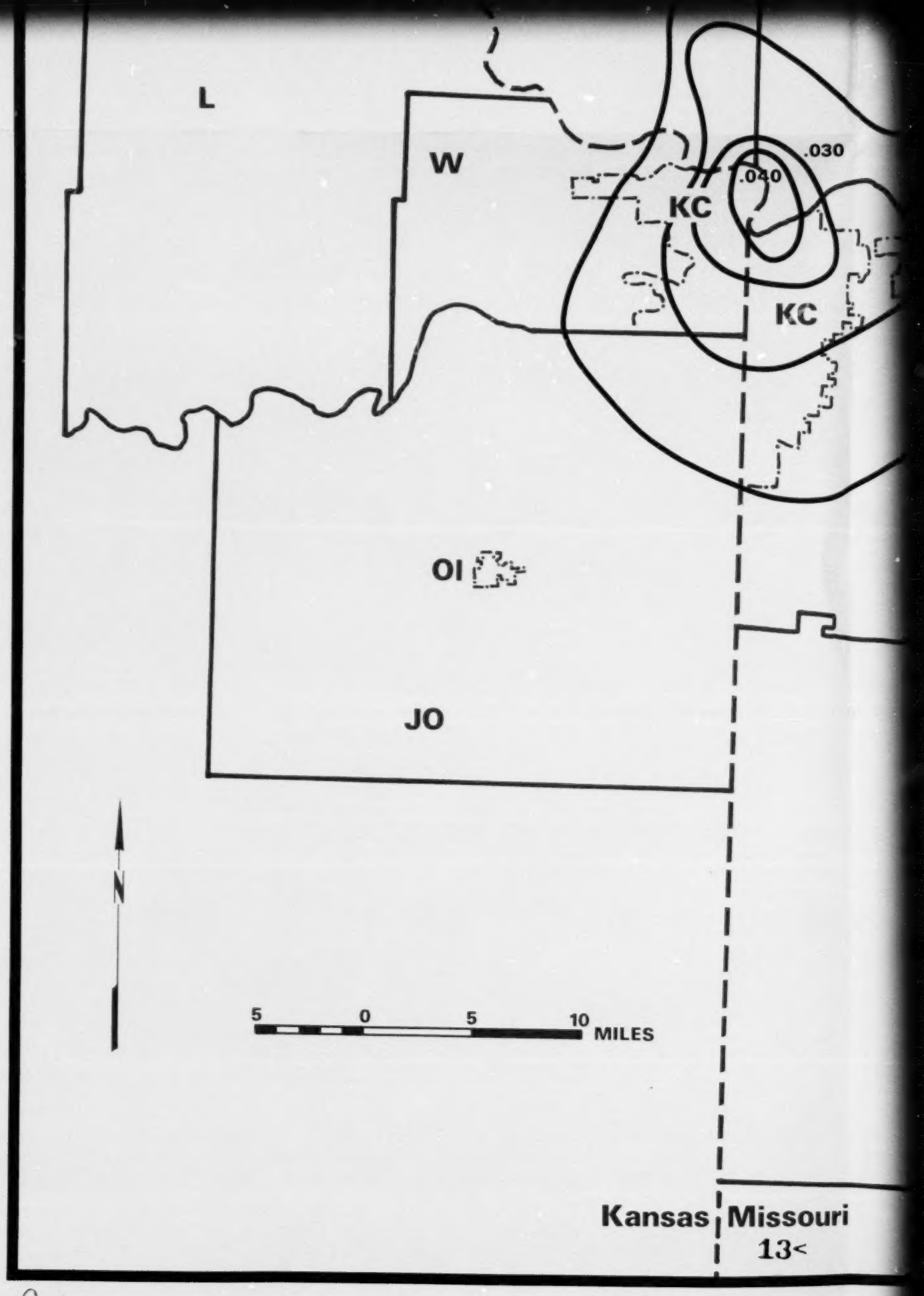
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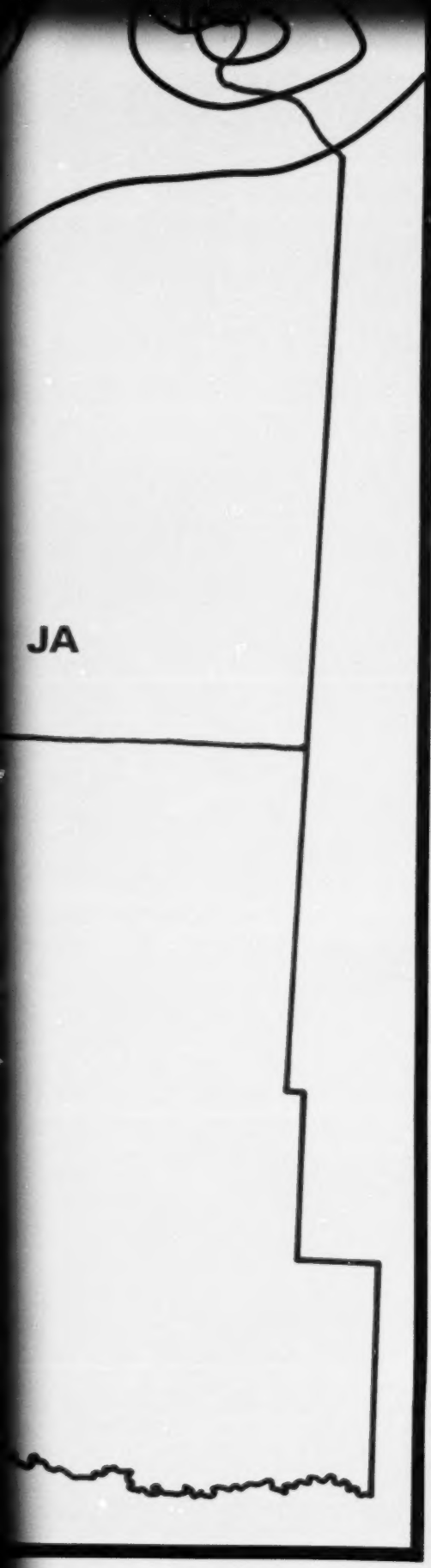

LEGEND

	Iso-intensity Line
PPM	Parts Per Million (Annual Average)

KANSAS CITY STUDY AREA

CA	Cass County
CL	Clay County
Ind	Independence
JA	Jackson County
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W	Wyandotte County

FIGURE II

PRE-ABATEMENT CONCENTRATIONS OF SULFUR OXIDES (PPM)

ERNST & ERNST
Washington, D. C.

TABLE I

EMISSION SOURCES OF

PARTICULATES (P) AND SULFUR OXIDES (SO_x)

Source Type	% Total Emissions	
	P	SO_x
Power Plants	10.2	51.9
Process Industries	36.5	34.5
Waste Disposal	27.7	0.3
Aggregated Small Sources	25.6	13.3
	100.0	100.0

Total Annual Particulate Emissions: 59,000 tons

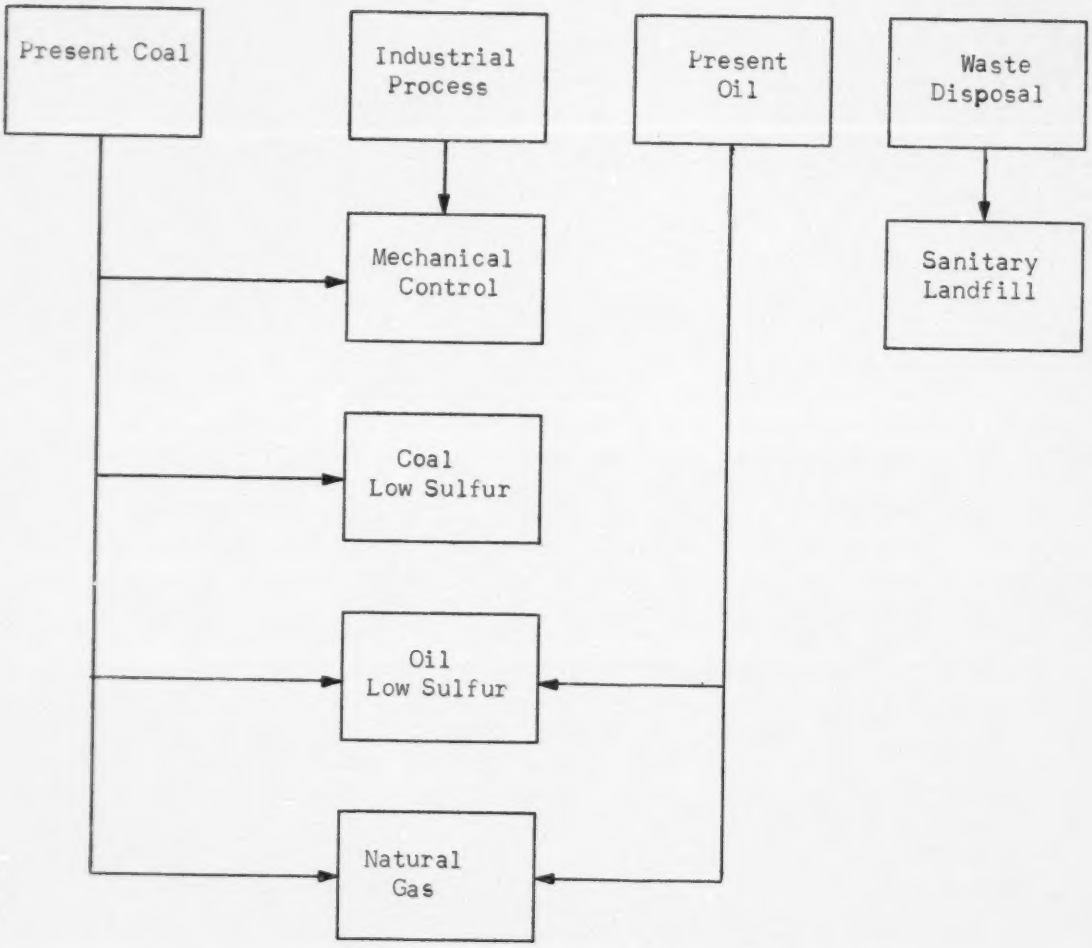
Total Annual Sulfur Oxide Emissions: 124,000 tons

FIGURE III

ALTERNATIVES FOR PARTICULATE AND

SULFUR OXIDES EMISSION CONTROL

(STATIONARY SOURCES)



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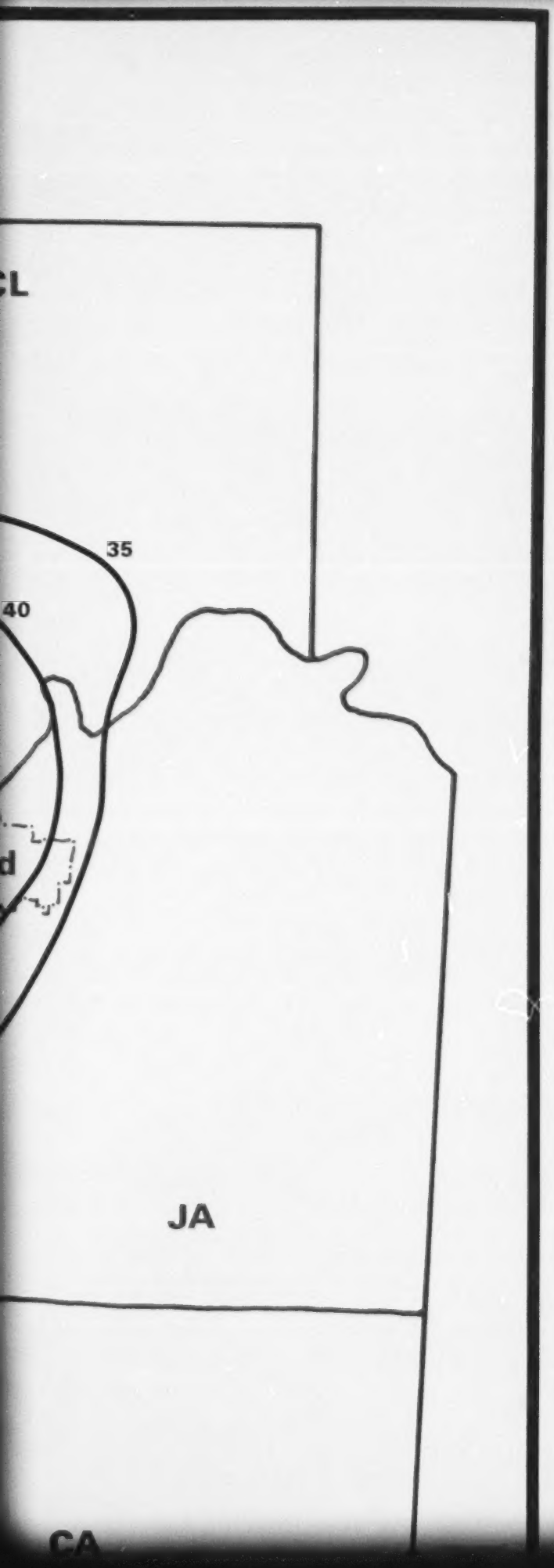

LEGEND

	Iso-intensity Line
$\mu Gm/M^3$	Micrograms Per Cubic Meter (Annual Average)

KANSAS CITY STUDY AREA

CA	Cass County
CL	Clay County
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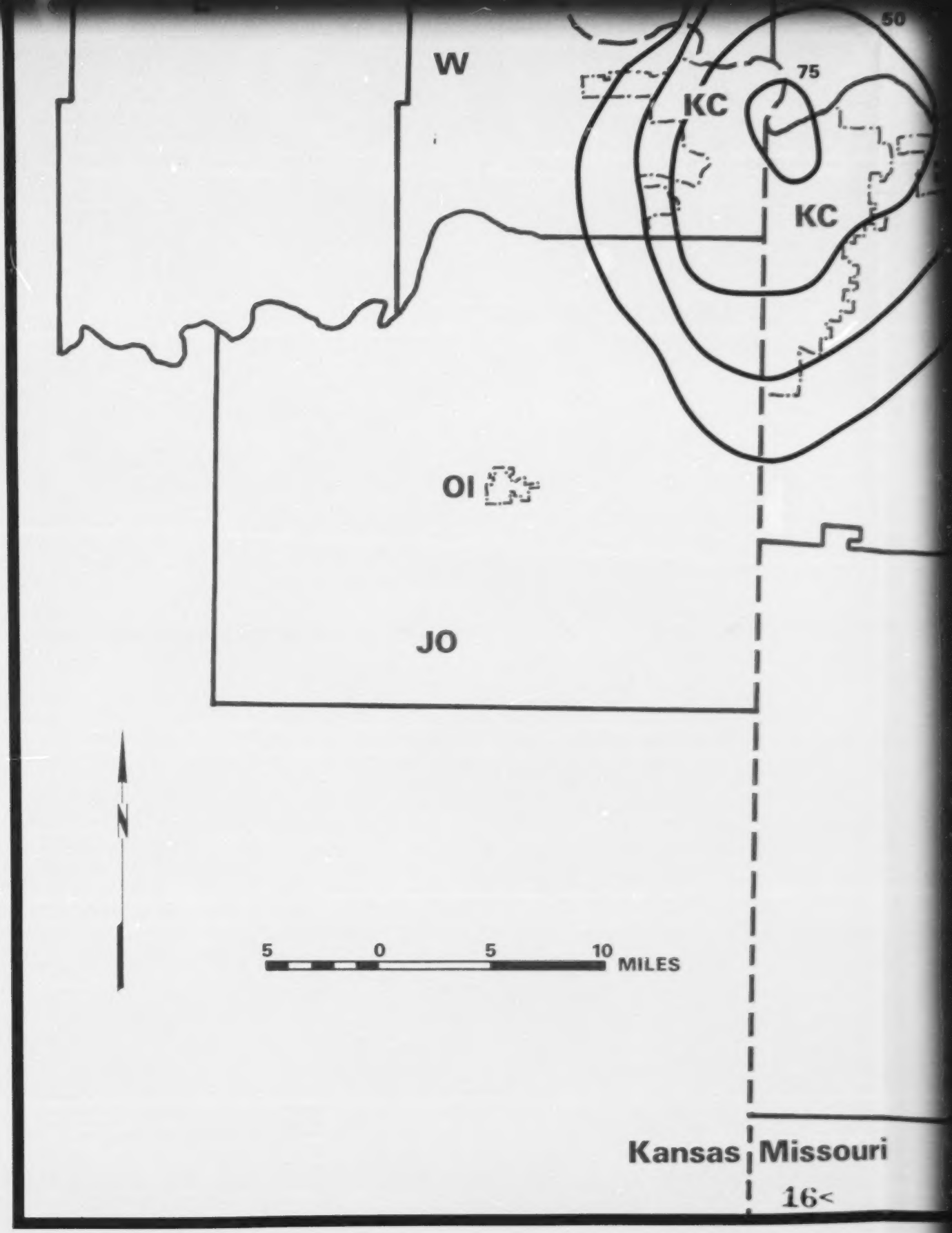
FIGURE IV



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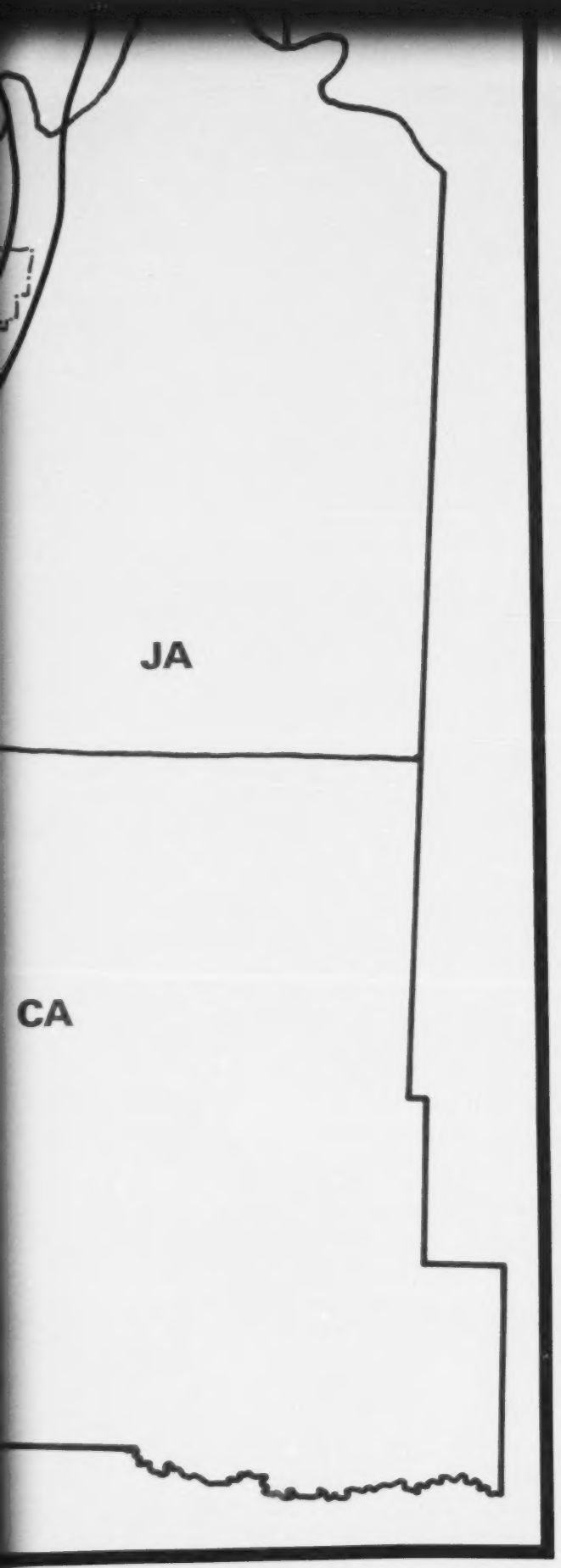

LEGEND

———	Iso-intensity Line
$\mu Gm/M^3$	Micrograms Per Cubic Meter (Annual Average)

KANSAS CITY STUDY AREA

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FIGURE IV

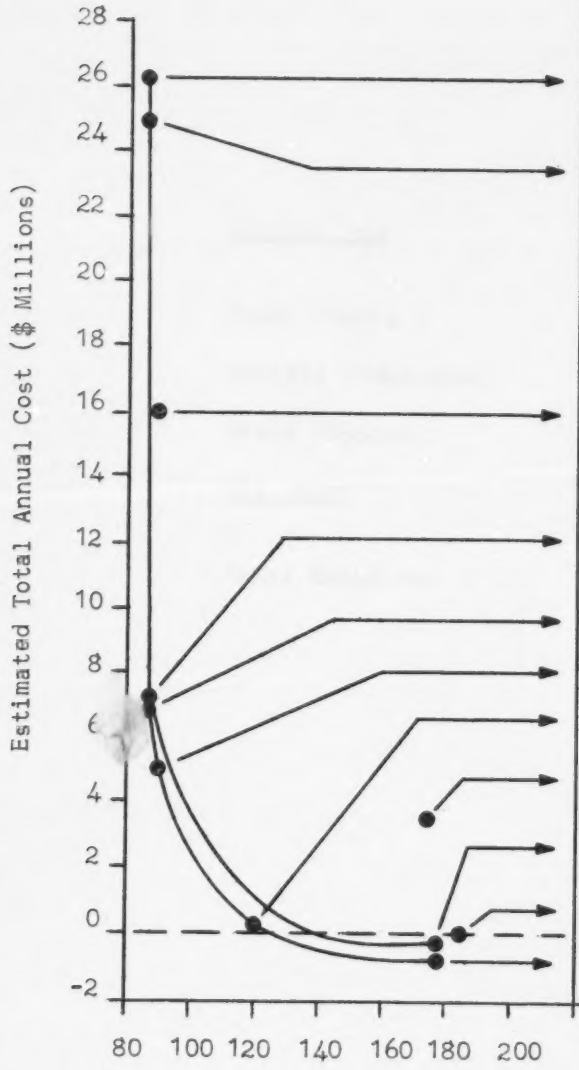
MAXIMUM SUSPENDED PARTICULATE REDUCTION ($\mu Gm/M^3$)

ERNST & ERNST
Washington, D. C.

FIGURE V

COMPARISON OF SIMULATED ABATEMENT

STRATEGIES FOR KANSAS CITY STUDY AREA



Strategy	Maximum Concentration		% Emission Reduction	
	µGms/M^3	ppm	Partic.	SO_x
Max. Control	85	0.015	69	81
Max. Partic. Control	85	0.038	69	48
EP Partic. Reduc. ≥ 20%	89	0.035	59	13
Least Cost Solution	86	0.023	66	42
"	86	0.040	68	7
"	89	0.040	59	7
"	120	0.040	22	5
2% Sulfur Fuels	175	0.035	10	38
Least Cost Solution	177	0.023	5	40
Base	184	0.046	0	0
Lowest Cost	177	0.040	5	5

TABLE II

COMPARISON OF PARTICULATE REDUCTIONS FOR
EACH SOURCE TYPE UNDER EQUI-PROPORTIONAL (EP) AND
LEAST COST (LC) STRATEGIES

Source Type	Source Emissions % Reduction and Cost ($ Millions)			
	LC		EP	
	%	$	%	$
Power Plants	68	0.2	53	0.2
Process Industries	81	0.7	71	8.6
Waste Disposal	81	4.1	100	6.4
All Other	-0-	-0-	1	0.8
Total Emissions	59	5.0	59	16.0